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THE UNIVERSITY OF ALBERTA

"SUPPLEMENTAL VALUE OF LOW GLUCOSINOLATE, LOW ERUCIC ACID RAPESEED MEAL AND UNPROCESSED FABA BEANS FOR PIGS"

BY

© AUGUSTINE MATHIAS NKADI EGBUIWE

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SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF
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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Supplemental Value of Low Glucosinolate, Low Erucic Acid Rapeseed Meal and Unprocessed Faba Beans for Pigs" submitted by A.M. Egbuiwe, in partial fulfillment of the requirement for the degree of Masters of Science in Animal Nutrition.

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TO MY FATHER

LATE AUGUSTINE M. EGBUIWE

ABSTRACT

Sixty four crossbred weanling pigs equalized in weight and between gilts and barrows were used in an experiment designed to study the effects of partial or total replacement of soybean meal (SBM) by various combinations of rapeseed meal (RSM) or faba beans (FB) on feed intake and performance as measured by average daily weight gain and efficiency of feed conversion. The eight diets were based on barley as the cereal grain with formulations differing in total protein during the starting, growing and finishing periods. The RSM consisted of 50-50 mixtures of two double low non-licensed varieties (1788 and 940). The FB (Vicia faba) were ground and unprocessed.

Treatment groups consisted of four pigs replicated twice. Pigs were fed the various diets from 4 weeks of age to market weight. Nitrogen and energy digestibilities of the various diets were determined using the 4N-Hcl method when the pigs attained an average weight of 38 kg. Blood samples for measurements of protein bound iodine, thyroxine, calcium, phosphorus, glucose, blood urea nitrogen, uric acid, cholesterol, total protein, albumin, bilirubin, alkaline phosphatase, serum lactic dehydrogenase and serum glutamic oxaloacetic transaminase, were taken from the

anterior vena cava one week after fecal sample collection for nitrogen and energy digestibilities. Animals were shipped for slaughter and carcass measurement when they attained an average weight of 88 kg.

Data during the starting, growing and finishing periods suggested that partial or total replacement of SBM by RSM, FB or combinations of RSM and FB had no significant effects on average daily feed intake, average daily gain or efficiency of feed conversion.

Nitrogen or energy digestibilities were unaffected by source of dietary protein. Carcass quality measurements were not significantly different between treatment groups. There was no indication that dietary protein source had any significant effects on the blood constituents measured.

Results indicated that RSM low in glucosinolates and low in erucic acid or ground unprocessed FB can fully replace SBM on an isonitrogenous and isocaloric basis in diets for pigs from 7 to 88 kg liveweight without any adverse effects on performance. Combinations of RSM and FB, RSM and SBM or FB and SBM as protein supplements also resulted in performance that did not differ significantly from that obtained when

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INTRODUCTION

Hunger and starvation are human problems that at present defy solution in spite of the technological advances encountered in almost every phase of modern day life. Hunger is prevalent in parts of India, Asia, and Africa and also in the poverty stricken areas of the United States despite her abundance of food.

The predicted increases in world population will accentuate these problems unless steps are taken to greatly increase food production or reduce population or both. Any attempt to combat hunger must give consideration to both improving the nutritive value of traditional food sources and to finding new food sources for direct human consumption or for feeding farm animals.

It has been estimated that the well being of approximately 85 percent of the world's population is affected in one way or another by the nutritional inadequacies of vegetable diets. (Albanese 1970). In recent years food shortages have been overcome partly by the development of new cereal strains. An example of the potential effect of new strains is the reported increase in rice yields by as much as 400 percent. Another example is the increase in amino acid concentration in opaque-2 corn varieties. Discovery and improvement of new protein supplements for animal feeds have also been made. In spite of these important advances, the need remains for continued assessment of new food sources because nutrient requirements are dynamic, changing constantly under the effects of changing physiological, genetic and environmental conditions of animals and man.

It is in the light of the above that the studies reported herein on the supplemental value of various combinations of new double low (low glucosinolate, low erucic acid) rapeseed meal (RSM) and faba beans (FB) for growing and finishing pigs have been carried out. These studies were undertaken at The University of Alberta Edmonton Research Station between April and September 1974.

The objectives of the experiment were:-

To study the effects on swine of various levels and combinations of RSM and FB in comparison with soybean meal as protein supplements to a cereal-based diet. Response criteria were (a) feed intake (FI), (b) average daily gain (ADG), (c) feed conversion (FC), (d) carcass characteristics and (e) certain blood constituents.

LITERATURE REVIEW

Because of the rapid rate of weight gain by pigs, it is important that this class of livestock be given adequate amounts of feeds containing nutrients in the right proportion in order to maximize their genetic potential. Since, however, swine and humans are monogastrics, they tend to come into close competition for foods. Thus adequate knowledge of the nutritive value of feed supplements, particularly the more expensive ones containing high levels of protein and ones not of direct use to humans, would facilitate their inclusion at optimum levels in the formulation of economical swine diets.

PROTEIN REQUIREMENTS OR ALLOWANCES

It is now established that for optimum growth consistent with a given species and age, there must be an adequate level of dietary protein containing the required essential amino acids. At sub-optimal dietary amino acid levels, tissue proteins are broken down to supply amino acids for the synthesis of essential body proteins. What the optimum levels of dietary protein and essential amino acids are, have been the subject of numerous studies.

Woodman et al (1939) indicated that pigs would grow satisfactorily on lower levels of protein in their diets than were generally recommended at the time. Their studies were aimed at establishing minimum levels of dietary protein consistent with optimum growth rate, feed effeciency and carcass quality. In further studies Woodman and Evans (1940, 1941, 1948) found that a barley-based diet including 7% fishmeal (FM) and containing 15% crude protein produced satisfactory results when fed to pigs from weaning to 41 kg liveweight. Comparative studies by these workers (Woodman & Evans 1951; Evans 1952) showed that 20% groundnut cake or 16% soybean meal (SBM) gave as good results as 7% FM in swine diets from weaning to 68 kg liveweight.

Pierce and Bowland (1972) conducted two experiments to assess the effects of dietary protein level, protein sequence and amino acid balance on performance and carcass quality of starting, growing and finishing pigs. Diets offered in the three stages contained 20, 17 or 14% crude protein, 14% crude protein supplemented with lysine or 14% crude protein with lysine and methionine. They found that feed intake, average daily gain and feed conversion efficiency were inferior in the starting period for pigs on the 14% crude protein diet compared with those fed 20 or 17% protein although a compensatory feed conversion effect in later growth stages was observed. They also noted that age to market averaged 2 - 3 weeks longer for pigs fed 14% protein throughout when compared with other protein sequences. They found that lysine and methionine supplementation of the low protein diet improved feed intake, rate of gain, feed conversion and loin eye area.

A number of investigations were carried out by Ashton et al (1955) on protein levels in swine diets. In one experiment, working with pigs from 36 - 200 lb (16-90 kg) protein levels were increased by increments of 2% from 10 to 20% of the diet. The results showed that the overall liveweight gain and efficiency of feed utilization improved as protein levels increased up to 16 percent. In two similar experiments with pigs in the same weight range these same workers found in one study that backfat thickness, percentage lean cuts and specific gravity increased linearly with increasing levels of protein from 10 to 20%; although in the second test, only specific gravity responded to increasing protein level, with carcass quality reaching a maximum at a level of 16% dietary protein and then declining as dietary protein levels increased.

Becker et al (1955) found that weight gain and efficiency of feed conversion of growing pigs improved with increasing protein levels from 12 to 14%, but unlike Ashton et al (1955) they found that protein levels had no significant effect on backfat thickness. Rerat and Henry (1964) reported that daily weight gain and feed utilization for growing and finishing pigs improved linearly with increasing protein levels up to 16% although differences were not significant. They also found that backfat thickness decreased with increasing protein levels, suggesting that energy was expended in the deamination of excess dietary protein. Holme et al (1965) reported that a 15% crude protein diet produced better carcass quality than a diet containing approximately 13% crude protein. Davis et al (1965) working with growing and finishing pigs observed that carcass quality can be improved by levels of up to 22% protein while weight gain and feed efficiency were improved at levels of up to 18 percent.

The effects of crude protein level on performance and body composition of pigs were studied by Wyllie et al (1969). They reported that reduced rate of gain resulting from sub-optimum protein intakes during early development tended to result in leaner carcass at slaughter. More recently, Tjong et al (1972) carried out studies on the effects of level of dietary protein during the early developmental period and of protein sequence on rate of gain, feed efficiency and carcass composition of pig. A superimposed study was conducted from 23 to 94 kg liveweight during which pigs were fed the following sequences of protein; 16-19-16, 16-16-13, 16-13-10, 20-19-16, 20-16-13, 20-13-10,24-19-16, 24-16-13, 24-13-10. Before the superimposed study they noted that pigs from weaning to 23 kg liveweight fed 16% protein required significantly more feed per unit weight of gain than those fed higher protein diets. On protein level sequences, they observed that pigs fed diets providing 19 to 16 and 16 to 13% protein level sequences during the grower - finisher stage, gained significantly faster and had improved feed/gain ratios compared with those fed at the lowest protein level sequence of 13 and 10 percent. These workers found that pigs fed diets providing a lower protein level sequence yielded carcasses with smaller cross-sectional area of the longissimus muscle. They also indicated that barrows gained significantly faster than gilts but carcasses from gilts tended to be superior to those from barrows in all carcass measurements except dressing percentage.

Gilster and Wahlstrom (1973) carried out two experiments on the effects of various protein sequences (10 to 20% -changed at 45 kg and 77 kg body weight). They found that dietary protein levels of 16-12-12 percent were adequate for daily gain. However for maximum feed efficiency they suggested levels of 18-14-12 percent.

Extensive work was conducted by Kornegay et al (1973) on all possible protein sequences from 16-16-16 to 12-12-12 with three protein levels 16, 14 and 12%. They concluded that a protein level sequence of 16-16-14 or 16-14-14 in corn-SBM diets optimized gain, feed efficiency and carcass merit. They indicated that there appeared to be no advantage from feeding the lower protein sequences (14-12-12 and 12-12-12) since the cost per kg of gain was just as high and carcass merit was less desirable than on the higher protein diets.

Tanksley (1974) has reviewed experiments dealing with protein levels and protein sequences. Several factors other than those mentioned above may affect the utilization or requirements for protein and for essential amino-acids. These are calorie, vitamin and mineral contents of the feed as well as age and sex of the pig. Factors affecting amino-acid availability include heat, processing techniques, amino acid antagonism or deficiency or both, absence or presence of inhibitors, protein structure and the source of the protein.

PROTEIN AND AMINO ACIDS

Protein utilization is a function of the amino acids present. Jones et al (1967) indicated that excesses or deficiencies of some amino acids in a protein may lead to an overall reduction in amino acid availability. The influence of excess lysine on the availability of arginine to chicks is an example of interaction between amino acids (Kakade 1970).

Harper, et al (1970) have described the conditions under which amino acids affect protein utilization. These come under (a) amino acid imbalance, (b) amino acid antagonism and (c) amino acid toxicity. An example of amino acid imbalance may be observed when gluten, which is poorly balanced in amino acids, was included in the diet as a source of lysine requirement of the rat for maximum growth was also increased (Munaver and Harper, 1959).

The amino acid requirements of swine have been studied in considerable detail. Some examples of these studies are given to emphasize that evaluation of proteins really involves an evaluation of essential amino acid levels in these proteins.

Studies of the adequacy of high-lysine corn have been reported by Pick and Meade (1970) who noted the effect of high-lysine corn: SBM ratios on concentrations of plasma free amino acids and performance. They found that rate of gain and efficiency of feed utilization of young pigs were increased with the inclusion of 4% or more of SBM in a diet based on high-lysine corn. They further observed that lysine requirement of pigs weighing 13.6 kg initially was met by 0.68 and exceeded by 0.78% lysine in the diet. Oestemer et al (1970) observed that additional methionine added to opaque-2 corns containing 0.275, 0.279 and 0.277% methionine and cystine did not improve rate of gain or efficiency of gain for growing pigs. Devilat and Skoknic (1971) indicated that lysine proved to be the first limiting amino acid in a 9% protein corn-FM diet for finishing pigs while Stockland et al (1971) observed that tryptophan was the first and only limiting amino acid in a 16% protein corn-FM and bone meal diet for 20 kg pigs. They noted that the addition of either lysine or methionine to these diets did not improve performance.

Heldt et al (1971) showed that lysine added singly or in combination with methionine or tryptophan to a 12% protein corn-SBM diet did not significantly improve performance of finishing swine on an unsupplemented diet. Baker et al (1969) found tryptophan to be the first limiting amino acid in corn protein for the growing pig with lysine as the second limiting amino acid. They observed that lysine supplementation of corn depressed weight gains unless tryptophan was also supplied. Stockland and Meade

(1969) were able to maximize gain of young pigs receiving a 16% corn-meat and bone scraps ration with supplemental tryptophan alone. They noted that supplemental tryptophan also resulted in reduced levels of plasma free lysine, isoleucine, threonine and urea. In another set of experiments Baker *et al* (1969) found that at least 56% of the sulphur amino acids requirement of the young pig could be supplied by cystine.

Using the serum amino acid level method Keith *et al* (1972) found that the methionine requirement of the 18 kg pig was 0.46% of the diet. The diet was cystine free. Brown *et al* (1972) using the nitrogen balance technique determined the total sulphur amino acids requirement to be not more than 0.17% of the diet for the finishing pig. These workers also reported the tryptophan requirement to be approximately 0.06% of the diet for the finishing pig. However, Lawrence (1972) working with growing and finishing pigs determined the tryptophan requirement to be greater than 0.1% of the diet.

Bravo *et al* (1970) in their re-evaluation of the isoleucine requirement of the growing pig, found this to be about 0.31% of the diet. They observed that levels of free isoleucine in plasma increased sharply once the requirement for maximum gain or gain/feed ratio was met.

in use in Canada or which have some potential use. These are rapeseed meal, whose production in Western Canada has increased tremendously in recent years; faba beans, now being grown to some extent and whose prospects seem very bright and soybean meal, whose nutritive value is well established. These will be dealt with in that order.

Rapeseed meal (RSM) as a protein supplement

History

Rapeseed production in Western Canada increased spectacularly during the period of 1967 to 1971. Production rose from 37 million bushels to 98.5 million bushels, (1850 million to 4925 million metric tons)(Rapeseed Association of Canada 1972). Rapeseed matures in a relatively short growing season and provides an alternative to cereal crops in a cropping program. Rapeseed is a good source of vegetable oil and as a by-product of oil extraction provides a high protein meal which may be fed as a portion of the diet for all classes of pigs (Bowland, 1972).

There are two types of rapeseed grown in Western Canada; *Brassica napus* (Argentine type) and *Brassica campestris* (Polish type). Of the two species *B. napus* has a greater potential yield of seed and oil than *B. campestris*; but varieties of the latter species are usually preferred in Alberta because they mature approximately two weeks earlier.

Composition of rapeseed

Rapeseed contains approximately 20% protein and 40% oil (Bowland 1971). Thus it is a high protein, high energy product. During processing, removal of the oil leaves RSM as a byproduct which may be used as a protein supplement. Cooking results in denaturation of rapeseed proteins. This is considered desirable as it renders protein more absorbed by pigs or poultry. Excessive heat however leads to production of meals that are nutritionally inferior and low in available lysine (Clandinin _et al_ 1959).

Crude fiber levels in RSM are higher and ash and nitrogen free extract levels are similar to those found in SBM and FB (Table 1).

Protein content

Protein content of RSM varies from 32 to 44% depending on such factors as the variety of seed, the environmental conditions under which the plant is grown and the processing conditions to which the seed is subjected during the extraction of oil (Clandinin _et al_ 1959). An average value for crude protein in commercial RSM is 36 percent (Bowland and Bell 1972). These same workers determined that the protein in RSM has an average digestibility by the pig of 76 percent. An examination of the essential amino acid composition of current commercial RSM shows levels are similar to SBM on an equivalent protein basis with RSM being slightly higher in methionine and slightly lower in lysine (Table 2). Based on amino acid composition, Bowland and Bell (1972) suggest that RSM and SBM can complement each other as protein supplements when added to cereal grains for feeding various classes of pigs.

Digestible and metabolizable energy of RSM

Digestible energy (DE) and metabolizable energy (ME) content of RSM are low compared with soybean meal (SBM) (Table 1). These values for pigs have often been mathematically derived by converting DE to ME by regression equations (NAS - NRC 1973). Saben et al (1971) reported extensive studies on the DE and ME of RSM for pigs. They obtained average values of 4.18 ± 0.12 kcal DE and 3.12 ±0.18 kcal ME/g RSM, which are lower than the average values of 4.74 ± 0.08 and 4.12 ±0.16 kcal/g observed for SBM. however the value of [illegible]18 kcal/g DE in RSM fed to pigs is higher than that for poultry which averages 3.92 kcal/g (Clandinin and Robblee 1966).

In another experiment, Bowland (1974) indicated that there were no significant differences in coefficients of DE and ME of diets containing RSM when he compared two types of RSM (low glucosinolate rapeseed meal and commercial rapeseed meal).

TABLE 1: AVERAGE NUTRIENT CONTENT OF SOYBEAN MEAL, RAPESEED MEAL AND FABA BEANS

(Percent on an air dry basis)

	SBM (44%)*	RSM*	FB*
Dry matter	89.0	92.0	87.5
Crude Fiber	7.0	9.3	6.7
Ether extract	0.5	1.0	1.1
Crude Protein	44.0	40.5	25.7
Calcium	0.25	0.66	0.08
Phosphorus	0.60	0.93	0.35
Digestible Energy	3338 kcal/kg	3062 kcal/kg	-

Source: *Composite Data - Bowland and Aherne (1974) University of Alberta

TABLE 2: AMINO ACID CONTENT OF RAPESEED MEAL, FABA BEANS AND SOYBEAN MEAL

(% amino-acid in protein)*

Amino Acids	Expeller RSM[1]	Prepress Solvent RSM[2]	Solvent RSM[3]	Solvent SBM[4]	Faba Beans[5]
Essential					
Alanine	4.23	4.37	4.46	4.20	3.92
Histidine	2.48	2.68	2.62	2.40	2.70
Isoleucine	3.70	3.72	3.86	4.69	3.82
Leucine	6.54	6.80	7.01	7.49	6.91
Lysine	4.68	5.65	5.83	6.22	6.43
Methionine	1.89	1.90	1.84	1.40	0.46
Phenylalanine	3.74	3.82	3.87	4.80	4.09
Threonine	4.14	4.31	4.38	3.80	3.64
Valine	4.75	4.86	4.96	5.00	4.34
Tryptophan	0.99	1.20	1.26	1.20	-
Non-Essential					
Arginine	5.21	5.60	5.61	6.44	9.20
Aspartic Acid	6.61	6.88	7.05	11.20	10.58
Cystine	1.10	1.17	1.48	1.29	1.44
Glutamic Acid	16.46	17.54	18.72	18.00	15.56
Glycine	4.73	4.92	5.08	4.60	4.03
Proline	5.86	6.15	6.30	4.89	4.87
Serine	4.12	4.32	4.41	5.00	4.85
Tyrosine	2.18	2.20	2.25	2.80	2.38

Values for RSM and SBM from D.R. Clandinin and Jean Heard; Dept. of Animal Science, The University of Alberta (R.A.C. 1972). Values for Faba beans from D.R. Clandinin and Goh; Dept. of Animal Science, The University of Alberta (1974).

1. Avg. of 7 samples of rapeseed meal.
2. Avg. of 29 samples of rapeseed meal.
3. Avg. of 9 samples of rapseed meal.
4. Avg. of 6 samples of soybean meal.
5. Whole unprocessed faba beans, avg. of a sample.

*Determined with the type 5AH Amino Acid Analyzer -- Japan Electron Ophis Co. Ltd. Tokyo Japan.

7

Toxic factors in RSM

Earlier reports indicated that the adverse effects of RSM on pig and poultry performance were due in part to the presence of glucosinolates. Enzymatic hydrolysis of glucosinolates by myrosinase, also found in the seed, yields toxic products such as isothiocyanates (Bell and Belzile 1965). The usual procedure of processing RSM inactivates the myrosinase. Josefsson (1970) indicated that the heating procedure for detoxification when applied to RSM is not as successful as with SBM since the heat intensity sufficient to destroy the glucosinolate could also denature the protein of RSM. Hussar and Bowland (1959) working with RSM as a protein supplement for swine and rats indicated that 10% dietary level of the meal depressed the rate of liveweight gain and in some cases reduced efficiency of feed utilization in both species. They also noted that total weight, histological sectioning and Iodine turnover rate of the thyroid gland indicated hypertrophy and other abnormalities of the gland in the animals feed 10% RSM.

Toxic factors in RSM have been reviewed in detail over the years since they were first identified. Bell at The University of Saskatoon and Bowland at The University of Alberta have spearheaded the Canadian research programs on the nutritive value of RSM for swine. RSM low in glucosinolate and rapeseed oil low in erucic acid have been developed. The development has been long and arduous and is now mainly historical. It is therefore not discussed in detail.

Palatability

There is indirect evidence to show that RSM is less palatable than SBM. When young pigs were offered diets in which RSM replaced up to one half of the SBM, there was no evidence of appetite depression. However, when young pigs were offered a choice of rations containing no RSM or up to 10% of either B. campestris or B. napus meal, they did not readily accept the rations with RSM (Bowland 1972).

RSM inclusion in swine diets.

Extensive experiments with starting, growing and finishing pigs have demonstrated that RSM may be fed as a portion of the diet for all classes of pigs. However, high dietary levels of RSM available several years ago caused thyroid gland enlargement, reduced rate of growth and adversely affected sow reproduction and lactation. (Bowland 1965).

Manns and Bowland (1963) using solvent extracted RSM, substituted on an equivalent protein basis from 0 to 100% for SBM in diets for pigs and rats from weaning through reproduction. In that experiment RSM and/or SBM represented 66 - 76% of the total supplemental protein and RSM accounted for up to 15.6% of the total diet. These workers found that the replacement of 20% of the SBM by RSM (that is 3.9% RSM in the total diet) did not significantly influence rate of gain or efficiency of feed utilization between 3 and 12 weeks of age or in pigs from 16 to 210 lbs. (7.27 - 95.3 kg) liveweight. They found that rate of gain and efficiency of feed utilization up to 8 weeks of age for rats or 110 lbs. (49.9 kg) in weight for pigs were poorer when 50% (that is 7.8% RSM in the total diet) or 100% (that is 15.6% RSM in the total diet) of the SBM in the diet was replaced by the RSM.

Schuld and Bowland (1967) observed depressed gain in gilts fed RSM in substitution for SBM during pregestation. This resulted in reduced litter weaning weight in the first reproductive cycle although no adverse effects on performance was observed in the second cycle.

Bayley et al (1969) in reproductive studies to evaluate RSM as a protein supplement for swine, using a 15% protein diet compared an isonitrogenous corn - SBM and corn - RSM diets. They observed that the substitution for SBM of 11% RSM in the diet did not affect the growth rate or reproductive efficiency.

In more recent studies, Saben and Bowland (1971) reported no deleterious effects when 8% solvent extracted RSM containing 2.4 g oxazolidinethione and 2.6 g isothiocyanate per kg meal was added in substitution for isonitrogenous levels of SBM for two reproductive cycles. They however noted there was a slight trend towards reduced litter size from gilts and sows fed RSM. Bowland and Hardin (1973) in two experiments fed RSM as partial replacement for SBM in the diet of growing gilts and of sows for up to three reproductive cycles. They found that gestation length, litter size and weight at birth and weaning were not influenced by dietary treatment in either experiment. They also found that thyroid weights and ratio of thyroid weight to body weight of representative 2 week old female pigs did not differ significantly between treatments. Their overall results suggested that up to 6% RSM of B. campestris origin is not detrimental to sow performance when the RSM is fed throughout growth and reproduction or when introduced suddenly at the time of breeding.

Bowland and Orok (1972-73) found that replacement of 50 or 75% peanut meal (PNM) with RSM resulted in improved feed intake, rate of gain and efficiency of feed utilization; suggesting that partial replacement of PNM by RSM results in an improved protein supplement. However an RSM supplement was not equal to a SBM supplement on an isonitrogenous basis.

These variations in results with RSM may be due to differences in processing methods or may be due to the development of varieties of rapeseed low in earlier mentioned toxic substances. Currently the recommended levels of inclusion of RSM in pig starter rations is 4 - 5% of the diet (Bowland and Bell 1972). For market pigs from 25 - 90 kg liveweight a level of 5 - 8% RSM in the diet provides a substitution level that is satisfactory with no significant influence on rate of gain, feed coversion and carcass quality (Bowland and Bell 1972). Although recommended level of RSM in pregestation, gestation and lactation diets particularly for young females may not exceed 3% of diet (Bowland and Bell 1972), recent studies in the University of Alberta indicate that a level of 5% or more may be included in the diet of this class of pigs (Bowland 1974).

With the introduction of new low glucosinolate cultivars of rapeseed, it is probable that recommended levels of RSM may be increased. At present one new variety of RSM has been licensed in Canada and other varieties are being produced. Studies with a non-commercial cultivar, B. napus cv. Bronowski have indicated that RSM from low glucosinolate varieties should be superior to current commercial RSM. For example, Omole and Bowland (1974) working on some mineral supplementation of pig diets containing either SBM or low glucosinolate RSM from B. napus cultivar Bronowski rapeseed noted that feed intake, weight gain, efficiency of feed utilization and digestion coefficients for nitrogen and energy were not significantly influenced by source of supplemental protein, suggesting that a low glucosinolate RSM could replace SBM on an isonitrogenous and isocaloric basis.

Faba beans as a protein supplement

History

Available literature suggests that interest in FB (Vicia faba L) has risen and fallen over the years since its earliest cultivation. This crop was known by the Hebrews, Greeks and Romans and was grown in such widely separated areas as China and all over Western Europe including Great Britian. As far as North America is concerned, it appears that the crop was planted in Mexico and surrounding territories as early as 5000 BC (Canada Grain Council 1972). The faba beans grown in Canada are varieties commonly called Tick beans. More recently, there has been increased research on production and utilization of FB. Aherne (1974) indicates that this may be due to the need to find new and alternate sources of protein and by the fact that increased production of cereals has stimulated the need for a break crop.

The acreage of FB grown in Western Canada increased from 2000 acres in 1972 to 21,000 acres in 1973 and this upward trend is expected to continue in 1974 (Aherne 1974).

Composition of faba beans

Bond and Toynbee-Clarke (1968) indicated that there may be differences in protein content between spring and winter varieties of FB. They showed that spring varieties consistently have higher crude protein than winter varieties. This may be of importance in Canada where the crop is sown in the spring. Eden (1968) in a survey also found differences in crude protein, crude fiber and hence nitrogen free extract (obtained by difference) between spring and winter varieties. On a dry matter basis, spring beans averaged 31.4% crude protein and winter beans 26.5 percent. Carpenter and Johnson (1968) indicated that FB protein is highly digestible and is well balanced with respect to amino acids other than the sulphur containing amino acids. Table 1 shows the amino acid composition of FB grown in Western Canada. Although the methionine plus cystine levels for FB seem very low compared with RSM and SBM, research by Aherne and McAleese (1964) indicate that supplementation with DL-methionine of rations containing 10, 20 and 30% FB did not enhance growth rate and significantly depressed feed efficiency when fed to pigs of 18 to 54 kg liveweight.

Digestible and metabolizable energy of FB

There appears to be no published research on DE or ME of FB for pigs, but Bottom (1963) working on broilers indicated that FB were low in ME. ME values by Carpenter and Johnson (1968) determined with chicks range between 2.52 and 2.80 kcal/g at 90% DM for three varieties of FB. Values by Waring and Shannon (1969) also for poultry were slightly less than those shown above. They obtained 2.47 kcal/g and 2.39 kcal/g for spring and winter varieties respectively.

Toxic factors in FB

Studies by Wilson et al (1972) showed in vitro evidence for the presence of a heat-labile inhibitor of trypsin in both the cotyledon and testa of FB. The activity of the inhibitor was destroyed by heating at 110° C for 40 minutes. These same workers reported that Borchers and Ackerson in one experiment with rats found no trypsin inhibitor activity although in further work, trypsin inhibitor activity was suspected when growth was significantly increased by autoclaving FB at 121° C for 30 minutes. This was so even when the FB sample used showed no trypsin inhibitor activity.

Palatability

As far as I can ascertain, no experiments have been conducted to indicate the palatability of FB. There is indication however that pigs might not accept readily rations containing more than 33% FB, on account of the somewhat bitter flavour of the bean (Canada Grain Council 1972).

Response to FB inclusion in swine diets

Research on the feeding value of FB in Canada is very scanty. However trials at Harper Adams Agricultural College, England, indicate that FB can be incorporated in all swine rations but more successfully in finisher rations, (Anonymous - Feedstuffs Nov. 27, 1972; Cole _et al_ 1971). In the trials carried out it was observed that there was a depression in weight gain with 20% FB in the grower ration although there were no adverse effects in finishing rations containing FB. In another experiment at this college, methionine and cystine supplementation was noted to impart slight beneficial effects in diets containing FB and it was concluded that the growth depressing effects of FB might be due in part to a methionine deficiency

Hansen and Clausen (1969) in a series of 16 experiments observed that methionine supplementation of diets containing FB gave no improvement in pig performance between 20 - 90 kg liveweight. The first set of experiments involved isonitrogenous substitution of SBM with FB. Each diet with FB was given with or without methionine. As indicated previously Aherne and McAleese (1964) also found that supplementation with DL methionine of rations did not enhance growth rates when FB was included at 30% level of the total diet.

Canada Grain Council (1972) cites a number of trials carried out in Germany which have indicated that FB harvested, dried and stored properly are excellent feed for fattening pigs and capable of fully replacing other vegetable protein carriers such as SBM provided that some animal protein is retained in the ration. Clarke (1970) cites Clausen and Hansen (1968) as having fed bacon pigs diets containing up to 30% FB and reported that raising the level of beans had no effect on the taste or consistency of the meat. He also indicated that blood iodine counts were normal. Two experiments by Henry and Bourdon (1972) indicated that in order to obtain favorable weight gains and feed conversion ratios, only about half of the supplemental protein or 15% FB may be included in diets of young pigs. However, during the finishing period, the pigs seem to accept higher levels of FB, about 30%, thus allowing for total replacement of SBM.

Recommended level of inclusion in diets

A summary of the above experiments indicate that FB are a satisfactory source of protein when fed in amounts not exceeding 15% of swine diets during the growing period or not exceeding 20% in the finishing period, (Aherne and McAleese 1964; Henry and Bourdon 1972).

(c) SBM AS A PROTEIN SUPPLEMENT

(i) History

The soybean (Glycine max) is perhaps one of the oldest cultivated crops. The crop was domesticated in North Central China from a related wild species G. ussuriensis. It became one of the five sacred crops of the Chinese along with wheat, rice, common millet and glutinous millet. It was introduced to neighbouring countries apparently in the early Christian era. China (Manchuria), Korea, Japan and the United States are the world's leading producing countries. Soybeans are also grown in the Philipines, Siam, the East Indian Islands and in certain parts of West Africa particularly

Nigeria and Ghana (Oyenuga 1959).

Results of nutritional trials with soybean were first published in the United States as early as 1804, whose introduction to the crop was by importation from China, Japan and Korea. Soybeans were first considered a hay crop but presently less than 1% of soybean acreage is planted for hay (Harmon _et al_ 1969).

The soybean plant is cultivated mainly for its oil bearing seeds. The extracted oil is used extensively for human consumption with the by-product being used as a protein supplement for all classes of livestock. In the United States maximum advantage has been made of this crop and its by-products.

In the mid-fifties, production of soybeans in the United States started to increase rapidly. At present, U.S.A. produces about 75% of the total world soybean crop and China produces about 20 percent. American exports of soybeans increased from 140 million bushels (4,666.7 million metric tons) in 1959 to 410 million bushels (13,666.7 million metric tons) in 1971. In 1972, the U.S. produced 1,283 million bushels (42,766.7 million metric tons) and in 1973 production exceeded 1,599 million bushels (53,300.0 million metric tons) of soybeans. It is estimated that half of U.S.A.'s annual exports of soybeans goes to Western Europe and about 25% goes to Japan (Schaible 1970).

Canada produces some soybeans, almost entirely in Ontario. In 1968 Canadian production was 9 million bushels (300 million metric tons) but this fell to 7.4 million bushels (246.7 million metric tons) in 1969. Decline in production has been steady within the last four years. Western Canada relies on the U.S.A. for importation of this crop.

TABLE 3: ANALYSIS* OF SOYBEAN MEAL SAMPLESδ

Sample #	Protein (%)	Ca (%)	P (%)	Se (ppm)	Mn (ppm)	Cu (ppm)	Zn (ppm)	Fe (ppm)
1389	48.8	0.45	0.66	536	40	32	112	214
1396	49.8	0.42	0.64	547	35	18	61	131
1403	50.0	0.48	0.72	570	37	24	68	150
1408	50.7	0.33	0.68	320	37	27	82	125
1409	50.9	0.30	0.66	430	51	21	81	125
Mean	50.0	0.40	0.67	480	40	24	81	150
Range	48.8-	0.30-	0.64-	320-	35-	18-	16-	125-
	50.9	0.48	0.72	570	51	32	112	219

* Expressed on an air-dry basis.

δ Alberta Soil and Feed Testing Laboratory, 1972.

Composition of SBM

SBM has a relatively high lysine content, a good amino acid profile and is a very uniform product. It is however relatively low in the sulphur containing amino acids (See Table 2) Its crude fiber content is intermediate between RSM and FB and the calcium and phosphorus levels are also intermediate between RSM and FB (See Table 1).

Protein content

The protein content of SBM is relatively high when compared with some plant proteins. Standard products are available with 44%, 48.5% or 50% protein depending on the percentage fiber present, which in turn is dependent on the method of processing. Although SBM is a relatively consistent product, there are some variations in SBM. Therefore it is recommended that analysis of this ingredient be carried out by researchers instead of assuming average composition (Harmon et al 1969).

At the Alberta Soil and Feed Testing Laboratory (ASFTL), five samples of SBM chosen at random by a commercial feed company were analyzed (Table 3). The results illustrate the point made by Harmon et al. The variations in composition found by Harmon et al were similar to those found by the ASFTL.

Digestible and metabolizable energy levels in SBM

The digestible energy values for SBM (44%) are higher than those of RSM and FB. Waring and Shannon (1968) working with colostomised laying hens indicate that the ME of SBM was 2.57 kcal/g and cite Matterson et al (1965), Titus (1961) and Bolton (1967) as having found ME from SBM (44%) to be 2.25 kcal/g, 2.44 kcal/g and 2.69 kcal/g respectively.

More recently Bowland (1974) in two experiments with pigs determined that the DE for SBM (44%) was 3179 and 3106 kcal/g and ME was 3087 and 3003 kcal/kg reespectively.

Toxic factors

McLaughlan (1972) cites Osborne and Mendel (1919) as having found that raw soybeans would not support the growth of rats unless the beans were cooked for three hours in a steam bath. Considerable experimental work has since since been carried out to assess the "anit-nutritional factors" present in raw soybean. McLaughlan indicates that when Ham et al (1945) discovered the presence of a heat-lablie trypsin inhibitor in raw soybeans, a hypothesis was made that the trypsin inhibitor was the cause of the lower nutritional quality of raw soybeans; for it was shown that animals excreted a higher percentage of the nitrogen intake and sulphur in their feed matter when compared with animals fed heated soybeans.

(Evans and McGinnis 1946). Thus Riesen et al (1947) suggested that the low nutritional value of raw soybean diet was due to decreased proteolysis.

Hendricks et al (1969) fed baby pigs up to 39.7% isolated soybean protein without increasing dietary phosphorus. Results showed severe depression in bone mineralization. Faber and Zimmerman (1970) fed infrared roasted soybeans to baby pigs and suggested that the protein from infrared roasted soybeans is not as well utilized as from SBM; but Jensen et al (1970) showed that roasting enhanced the utilization of soybeans for swine through the three growth stages. Essentially the same results were obtained by Carlisle et al (1973). They noted that roasted and extruded soybeans were effective sources of protein supplements in fortified corn-soy diets for pigs weaned at five weeks and fed throughout the growing-finishing period. Thrasher et al (1973) noted that roasted soybeans improved feed efficiency 5% compared to SBM when fed in both corn and sorghum diets throughout the growing-finishing period. They also noted that source of protein has no significant effect on carcass cutability although carcasses from pigs fed roasted soybean had softer fat.

Young and Smith (1973) found that pigs fed cooked soybeans or SBM had similar performance which was superior to that of pigs fed raw soybeans. They noted that the addition of alkali to the cooking water resulted in poor performance of pigs fed cooked soybeans while addition of copper sulphate to the water gave inconsistent results.

Young (1970) summarized the results of a series of trials in which raw soybeans were compared with soybean meal in swine rations. In all cases, weight gains and feed efficiency ratios were lower when raw soybeans were fed. Fortunately none of these factors discussed is of any practical importance as the normal method of oil extraction from soybean provides enough heat for inactivation of these growth inhibitors in SBM (Rachis 1966).

Feeding value of SBM

SBM is a high quality protein supplement capable of being used for all classes of livestock. In most recent research work, SBM is used as a standard positive control against which other protein sources are evaluated (Bowland 1972).

Some mention has been made of the feeding value of SBM in my reviews of RSM and FB. I shall therefore restrict myself to trials involved with baby pigs and protein supplements other than RSM and FB.

Hays et al (1959) have compared dried skim milk (DSM) and SBM in pig starter rations and found that daily weight gains and feed conversion efficiency were significantly improved on the DSM diet compared with the SBM diet. They however noted improved response in pigs fed SBM plus 0.05% D-L-methionine.

Combs et al (1959) carried out two experiments with weanling pigs from 2 - 8 weeks of age in which they compared DSM, SBM and FM. In the first experiment results indicated that average daily weight gains and feed consumption were significantly improved by feeding DSM rather than SBM or FM. However, in the second experiment in which they compared SBM and PNM results showed that pigs on SBM diet had significantly better average daily gain and feed consumption than pigs on PNM. They indicated the following rating of the diets used: DSM>SBM>FM>PNM.

Jones and Maxwell (1973) reported satisfactory but lower performance compared with a SBM control diet when a low gossypol-free cottonseed meal (pre-press solvent) and a high gossypol-free cottonseed meal (direct solvent) were fed for three reproductive cycles in gestation and lactation diets containing 16% protein.

Results indicated that number of pigs farrowed and weaned were significantly higher in the cottonseed meal diet than in the SBM diet. However, pig weights at birth and at 35 days of age were significantly higher in the SBM diet than in the cottonseed diets.

Level of inclusion of SBM

Level of SBM supplement used in a diet is a function of protein content of the meal and of the cereal grains which are being supplemented. All the reviews cited above indicate that SBM can be included in all categories of swine diets at any level consistent with the protein level required in the diet. It is in the light of the above that SBM is being used as a positive control in the study reported herein.

THYROID FUNCTION

As indicated previously, the glucosinolate present in currently available commercial RSM may be converted by myrosinase to potentially thyrotoxic compounds. The main function of the thyroid hormone is of oxidative reactions and regulation of metabolic rates in the body. The tissues of hypothyroid animals exhibit a low rate of oxygen consumption. Conversely, those of hyperthyroid animals take up oxygen at an accelerated rate. In the absence of adequate quantities of the hormone, the body processes decrease, cholesterol levels in the body are increased by lipolysis and the liberation of fatty acids from the tissues decrease. In hyperthyroid states, the reverse occurs. Some of the symptoms are increased oxygen consumption, nervousness and loss of weight. In moderate concentrations, the thyroid hormone has an anabolic effect, causing an increase in RNA and protein synthesis; an action which precedes increased basal metabolic rate. Harper et al (1[illegible]) cites Sokloff et al (1963) as indicating that facilitation of protein synthesis occurs not only by increasing RNA synthesis at the nuclear level but also by increasing translation of the message contained in messenger RNA at the ribosome where protein synthesis occurs. It may also increase protein synthesis by stimulation of growth hormones. Adequate amounts of thyroxine appears to stimulate most oxidative enzyme systems. However high concentrations produce an opposite effect resulting in negative nitrogen balance, depressed protein sythesis, increased turnover of carbohydrates and lipids and calcium mobilization from bone.

Iodine uptake is against a gradient. Thus it is energy dependent and can be inhibited by cyanide or dinitrophenol. Within the thyroid iodide is oxidized to an active form; a reaction which is catalyzed by a peroxidase requiring hydrogen peroxide as a source of oxygen.

The receptors of the activated iodine are the tyrosine residues in the macroglobin protein, thyroglobulin. Iodination of the tyrosines in thyroglobulin occurs first in position 3 of the aromatic nucleus and then at position 5, forming monoiodotyrosine and diiodotyrosine respectively. Under normal condition the 2 are present in approximately equal concentration, but with iodine deficiency more monoiodotyrosine is formed. It is assumed that the coupling of two molecules of diiotyrosine (DIT) then occurs to form tetraiodothyronine or thyroxine (T4). Coupling of monoiodotyrosine (MIT) with DIT also occurs to form triiodothyronine (TIT,T_3).

Within the plasma, thyroxine is transported and associated with two glycoproteins called thyroxine-binding globulin (TBG) and thyroxine-binding prealbumin (TBPA). When large amounts of thyroxine are present and the binding capacities of these specific carrier proteins are exceeded, thyroxine is bound to serum albumin. The total circulating thyroid hormone is measured as protein-bound iodine (PBI). In hyperthyroidism, PBI is elevated and the reverse happens in hypothyroidism.

GENERAL FUNCTIONS OF BLOOD CONSTITUENTS STUDIED

Levels of blood constituents have been used to indicate state of health of given species of animal. The following are some blood constituents of the pig studied.

Calcium

Calcium is present in the body in larger amounts than any other cation. Almost all of it is in the bones and teeth. The very small quantity not in the skeletal structures is in the body fluids and is in part ionized. Ionized calcium is of importance in blood coagulation, in the function of the heart, muscles, and nerves, and in the permeability of membranes (Harper _et al_ 1970).

The ability of animals to utilize the calcium in foods varies considerably. On a high-protein diet, 15% of the dietary calcium is absorbed; on a low-protein diet, 5%. Phytic acid in cereal grains interferes with calcium absorption by forming insoluble calcium phytate in the intestine. Oxalates in foods may have a similar effect. Other intestinal factors which influence absorption of calcium include:

A. pH: The more alkaline the intestinal contents, the less soluble the calcium salts.

B. Phosphate: If the Ca:P ratio is high, much $Ca_3(PO_4)_2$ will be formed and absorption diminished.

C. Presence of Free Fatty Acids: When fat absorption is impaired, much free fatty acid is present. These free fatty acids react with free calcium to form insoluble calcium soaps.

D. Vitamin D: Vitamin D promotes the absorption of calcium from the intestine.

The blood cells contain very little calcium. Most of the blood calcium is therefore in the plasma, where it exists in 3 fractions: ionized (so-called diffusible calcium), protein-bound (non-diffusible), and a small amount complexed probably as the citrate. All of these forms of calcium in the serum are in equilibrium with one another. In the usual determination of calcium, all three fractions are measured together.

A decrease in the ionized fraction of serum calcium causes tetany. This may be due to an increase in the pH of the blood (alkalotic tetany; gastric tetany) or to lack of calcium because of poor absorption from the intestine, decreased dietary intake, increased renal excretion or parathyroid deficiency. Increased retention of phosphorus also predispose to low serum calcium levels.

Alkaline Phosphatase

Phosphatases are enzymes capable of hydrolyzing monophosphoric esters with the liberation of inorganic phosphate. Simensen(1963) cites Erdtman (1928) as noting that alkaline phosphatases have their maximum activity at pH 8.5 to 9.5 and are activated by Mg ions. Alkaline phosphatases are present in almost all body tissues, but only the alkaline phosphatase of osteoblasts has its site of funtion outside of the cells. Thus, some of the osteoblastic phosphatase continuously reaches the plasma and circulates in the blood stream. Simeson (1963) notes that alkaline phosphatase found normally in the bile tends to remain at constant concentration but increases in obstructive jaundice. Luecke _et al_ (1958) in their study of the effect of various levels of dietary calcium both with and without supplemental zinc on blood serum levels of alkaline phosphatase in swine, found that zinc supplementation produced a significant increase in serum alkaline phosphatase values.

Phosphorus

Phosphorus is found in every cell of the body, but most of it (about 80% of the total) is combined with calcium in the bones and teeth. About 10% is in combination with proteins, lipids, and carbohydrates, and in other compounds in body muscle. The remaining 10% is widely distributed in various chemical compounds.

The metabolism of phosphorus is in large part related to that of calcium as described above. The Ca:P ratio in the diet affects the absorption and excretion of these elements. If either element is given in excess, excretion of the other is increased. The optimal ratio is 1:1 when the intake of vitamin D is adequate.

An increase in carbohydrate metabolism, such as during absorption of carbohydrate, is accompanied by a temporary decrease in serum phosphate. A similar decrease may occur during absorption of fats. In diabetes mellitus, there is a lower concentration of organic phosphorus but a higher concentration of inorganic phosphorus in the serum.

In rickets of the common low-phosphate variety, serum phosphate values may be low.

Phosphate retention is a prominent cause of the acidosis in severe renal disease, and the resultant elevated serum phosphorus also contributes to the lowered serum calcium. Blood phosphorus levels are also high in hypoparathyroidism and low in hyperparathyroidism. A low blood phosphorus together with an elevated alkaline phosphatase may be characteristic of rickets and renal tubular defects in the reabsorption of phosphate.

Uric acid

This is the end product of purine metabolism in most mammals. Uric acid in the plasma is filtered by the glomeruli but is later partially reabsorbed by the renal tubules (Harper 1971). Glycine is believed to compete with uric acid for tubular reabsorption of uric acid and urinary excretion of uric acid can also be increased by the administration of hormones of the adrenal cortex. Elevated levels of urates in blood and uric acid in the urine may be indicative of liver problems. Because of differences in enzyme systems, uric acid is of less significance in the pig than it is in the human.

Bilirubin

This is also a liver test based on the secretory and excretory functions of the liver and bile pigment metabolism. Increased bilirubin in the blood may indicate signs of jaundice. Since the yellow color in this test is due principally to bilirubin, certain other pigments which resemble the yellow colour of the bilirubin, for example, carotene in the blood may lead to apparent high values.

LDH and SGOT

Serum lactic dehydrogenase (LDH) and serum glutamic-oxaloacetic transaminase (SGOT) measure blood enzyme activity associated with liver activity.

(g)Glucose

Blood glucose concentration is dependent upon a wide variety of factors. The concentration at any time is the net result of the rates of entry by carbohydrate metabolism and of removal of glucose in the circulation by the muscles. Kaneko (1970) indicates that glucose may be supplied by intestinal absorption of dietary glucose, production from other dietary carbohydrates, from amino-acids (gluconeo-genesis) or from glycogen. He indicates that the absorptive process may vary with the degree of thyroid activity and hormonal influences such as epinephrine and glucagon which are involved in the release of glucose from glycogen. Removal of glucose, on the other hand is dependent on the rate of utilization of glucose by the animal. At high levels of glucose in the blood, the rate of glucose uptake by tissues such as muscles and liver increases. The presence of insulin increases the rate of utilization either by increased transfer to the muscle or increased phosphorylation in the liver. The liver can thus supply as well as remove glucose and therefore occupies a central position in the regulatory mechanism of blood glucose concentration; but the metabolic activities of liver however are primarily directed toward supply rather than utilization of glucose.

Thus any disorders in carbohydrate metabolism may be indicated in blood glucose levels.

EXPERIMENTAL PROCEDURES

MATERIALS AND METHODS

(a) Animals and housing:

Sixty four crossbred pigs weaned at an average age of four weeks were used in this trial. All pigs were routinely injected with 2 ml imposil 200[1] within three days of age. Male pigs were castrated at one week of age. All pigs were weighed at the start of the trial, balanced for sex and then randomly allotted but balanced as closely as possible for weight and litter. Animals were then moved into their experimental barn into their various treatment groups on a concrete floored thermostatically maintained at a temperature of 21-22° C. Each treatment group consisted of four animals (two barrows and two gilts) replicated twice. All animals in the first replicate were on the same side of the barn. A passage seperated animals in replicate two which was set up one week later. Thus the second replicate was on the opposite side of the barn.

Water was provided on an ad libitum basis, supplied

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[1] Imposil 200 -- Iron dextran complex. Fisons (Canada) Limited. 26 Prince Andrew Place, Don Mill, Ontario. Contains 200 mg iron in every 2cc dose.

TABLE 4: FORMULATION AND COMPOSITION OF THE FINISHER DIETS

Diets Ingredients[1]	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM
Barley	87.5	82.0	74.6	80.5	79.0	77.8	81.0	84.7
SBM	9.0	-	-	-	-	-	4.5	4.5
RSM	-	14.5	-	11.0	7.5	3.7	-	7.3
FB	-	-	21.9	5.0	10.0	15.0	11.0	-
Iodized Salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Ground limestone	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Calcium phosphate	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Min-Vit-Mix[2]	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Calculated Composition								
Crude Protein %	14.0	14.2	14.0	13.8	14.0	13.9	13.9	14.2
Calcium %	0.68	0.87	0.79	0.85	0.83	0.81	0.88	0.81
Phosphorus %	0.65	0.73	0.64	0.70	0.68	0.66	0.64	0.685
D.E. (kcal/kg)	3032	3044	3003	3004	3004	3004	3017	3018
Proximate analysis								
Dry matter %	87.2	87.9	88.0	87.4	88.1	88.5	87.6	87.7
Crude protein %	14.7	13.1	14.5	14.5	14.6	13.4	14.9	13.5
G.E. (kcal/kg)	3869	3869	3785	3777	3685	3760	3745	3769
Ash %	8.4	7.2	6.4	7.6	7.7	7.3	8.1	7.9

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[1] SBM = Soybean meal 48.5%
RSM = Rapeseed meal 36% 50-50 mixture of double low varieties - Altona 00(1788) and Nipawin 940. This mixture was prepared by the U. of A. Swine Unit.
FB = Faba beans 26.5%

[2] Supplied the following per kg of diet: 4400 i.u. vitamin A; 665.5 i.u. vitamin D 11 i.u. vitamin E; 66 mg coline chloride; 1.65 mg folic acid, it also provides cobalt 2.8 ppm; copper 24.6 ppm; iron 294.1 ppm; manganese 76.2 ppm; zinc 88.g ppm and iodine 1.5 ppm, in addition it provides 110 mg per kg of diet of oxytetracycline.

TABLE 5: FORMULATION AND COMPOSITION OF THE STARTER DIETS

Diet Ingredients	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM
Barley (11%)	75.6	70.1	62.7	68.6	67.1	65.9	69.1	72.8
SBM	20.0	11.0	11.0	11.0	11.0	11.0	15.5	15.5
RSM	-	14.5	-	11.0	7.5	3.7	-	7.3
FB	-	-	21.9	5.0	10.0	15.0	11.0	-
Iodized salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Ground limestone	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Calcium phosphate	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Min-Vit-Mix	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Calculated composition								
Crude protein %	18.0	18.3	18.0	18.2	18.0	17.9	18.0	18.1
Calcium %	0.98	1.05	0.97	1.04	1.01	0.99	0.98	1.02
Phosphorus %	0.66	0.74	0.66	0.72	0.70	0.68	0.66	0.70
D.E. (kcal/kg)	3027	2999	2999	2664	3001	3001	3013	3013
Proximate analysis								
Dry matter %	87.5	87.8	87.4	88.3	87.5	88.2	87.1	87.3
Crude prot. %	18.2	18.0	18.2	17.8	17.3	17.6	18.6	17.5
G.E. (kcal/kg)	3817	3851	3788	3516	3727	3861	3725	3860
Ash %	6.6	6.1	6.2	6.8	5.4	7.1	5.2	6.1

TABLE 6: FORMULATION AND COMPOSITION OF THE GROWER DIETS

Diet Ingredients	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM
Barley	82.0	76.5	69.1	75.0	73.5	72.3	75.5	79.2
SBM	14.5	5.5	5.5	5.5	5.5	5.5	10.0	10.0
RSM	-	14.5	-	11.0	7.5	3.7	-	7.3
FB	-	-	21.9	5.0	10.0	15.0	11.0	-
Iodized salt	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Ground limestone	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Rock phosphate	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Min-Vit-Mix	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Calculated composition								
Crude prot. %	16.1	16.3	16.1	16.2	16.1	15.9	16.1	16.2
Calcium %	0.81	0.88	0.81	0.87	0.85	0.83	0.81	0.85
Phosphorus %	0.65	0.74	0.65	0.71	0.69	0.67	0.6	0.69
D.E. (kcal/kg)	3044	3015	3015	3015	3015	3016	3029	3029
Proximate analysis:								
Dry matter %	87.4	87.8	87.5	87.4	87.1	88.1	87.0	87.6
Crude prot. %	16.2	16.0	16.1	16.8	16.3	16.2	16.3	16.0
G.E. (kcal/kg)	3771	3867	3728	3858	3694	3859	3715	3729
Ash %	8.4	8.4	6.5	7.4	7.1	7.8	8.2	7.5

by automatic fountains into each treatment pen. Feed was provided in self feeders on an ad libitum basis. Weekly feed intake was recorded. At approximately 8 weeks of age, all animals were vaccinated against erysipelas infection with Erysipelas Bacterin[2].

(b) Weight recording:

Animals were individually weighed once every week, on Wednesdays, throughout the duration of the trial.

(c) The diets:

The diets of each treatment group through the three growth phases are shown in Tables 4,5, and 6. The dietary protein supplements were SBM, RSM and FB. For convenience, the finisher diets (Table 4) were formulated and then modified to provide the various starter and grower diets (Tables 5 and 6). In the finishing stage, the diets were calculated to supply approximately 14% crude protein in each treatment in accordance with the NRC - NAS Nutrients Requirements of swine (1973). The protein supplement in diet 1 was supplied entirely by SBM. Protein supplements in diets 2 and 3 were provided by RSM and FB respectively. Diets 4, 5 and 6 were formulated such that the various fractions of RSM and FB indicated supplied the required protein. The same applied to diets 7 and 8 whose supplemental protein came from one half SBM and one half FB and from one half SBM and from one half RSM respectively. ?

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[2] Erysipelas Bacterin -- E. Rhusiopathia (precipitated hydroxide). Colorado Serum Company. 4950 York St. Denver, Colorado. U.S.A.

The grower diets were calculated to provide 16% crude protein in each diet. In order to maintain the various percentages of RSM and FB in each treatment, an additional 2% protein was supplied by SBM. This was done by adding 5.5% SBM at the expense of barley in each of the eight treatments. The starter diets supplied 18% crude protein. To obtain this protein level the same principle used above was adopted. Thus, by adding 11% SBM to each of the dietary treatments, at the expense of barley, the dietary protein level was met.

(d) Digestibility trials:

Energy and Nitrogen digestibility.

Fecal samples were collected when a lot of 4 pigs averaged 38 kg on the grower diets. Collections were made from individual animals within a treatment but bulked for that treatment group. Daily collections were stored in a refrigerator at a temperature of about 4° C and at the end of the third collection, samples were placed in a forced-air oven[3] at 60° C. Drying was carried out for 3 days after which the samples were finely ground in a laboratory mill.[4]

Samples of feed and feces were analysed for dry matter and total Kjeldahl nitrogen according to the methods of A.O.A.C. (1965). A commercial "Kel Pac"[5] was used as the catalyst for nitrogen determination and ammonia was collected in 4% boric acid. Energy content of feeds and feces were determined in Parr Oxygen Bomb Calorimeter.[6]

Digestibility of diets was estimated using the method of McCarthy _et al_ (1974). The ash of both feces and feed which is insoluble after boiling in 4N-HCL for 30 minutes is used as an internal indicator, giving a digestibility coefficient similar to the chromic oxide method. The indicator was used to calculate % digestibility as outlined by Maynard and Loosli (1969).

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[3] Style V31, Dispatch Oven Company, Minneapolis, Minn; U.S.A.

[4] Janke and Kunkel K.G. Fabirk Chem. Phys. Apparate and Maschinen. Staufen; Br. Type A10.

[5] Catalyst containing HgO, K_2SO_4, and $CuSO_4$ was supplied by Mateson Scientific East Rutherford, N.J. U.S.A.

[6] Parr Instrument Co., Moline, Illinois. Temperature changes recorded by a Brown Electronik Recorder manufactured by Honeywell Regulator Co., Philadelphia, Penn., U.S.A.

$$\text{Percentage digestibility} = 100 - \left(100 \times \frac{\%\ \text{indicator in feed}}{\%\ \text{indicator in feces}} \times \frac{\%\ \text{nutrient in feces}}{\%\ \text{nutrient in feed}}\right)$$

(e) Blood constituents:

Individual blood samples were obtained by anterior vena cava puncture from each animal one week after the fecal samples were taken. Blood samples from animals in replicate 2 were taken one week after those from replicate 1. These samples were analysed by a commercial company in Edmonton[7]. Analysis was carried out for the following constituents:-

(a) protein bound iodine (PBI)
(b) thyroxine (T^4)
(c) calcium
(d) phosphorus
(e) glucose
(f) blood urea nitrogen (BUN)
(g) uric acid
(h) cholesterol
(i) total protein
(j) albumen
(k) bilirubin
(l) alkaline phosphatase

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[7] Hanson and Associates Medical Laboratory. 203 Professional Building, Edmonton, Alberta

(m) serum lactic dehydrogenase (LDH)

(n) serum glutamic oxaloacetic transaminase (SGOT). Interest in the blood analysis lies mainly with PBI and T^4 which measure thyroid gland activity. The analysis of the other constituents came as a package from the commercial company. However, these other constiuents have been considered in the Literature Review and the importance of some of them will be discussed under Results. Methodologies of individual tests are shown in the Appendix.

(f) Slaughter of animals:

It was decided from the onset of the trial that any animal that attained a liveweight of 90 kg on any weighing day would be shipped for slaughter with the proviso that the fourth animal in each treatment group in each replicate was also shipped when the third animal attained this weight. This criterion was not strictly adhered to, particularly during the final week of the experiment. The contributory factor was the shortage of RSM for ration compounding. However, the average weight of the animals exceeded 80 kg and they were thus of sufficient weight for normal grading. Record of Performance of Swine carcass measurements were obtained on an individual carcass basis. Data could not be obtained for about one-third of the animals shipped for measurement. What actually happened was that 23 animals were shipped on Wednesday the 4th of September when they attained market weight. Following the normal procedure, covering letters accompanying the animals and requesting measurements were sent to the Superintendent, Swift Canada Limited and to the Government Grader, Agriculture Canada. Because of an error, the animals were slaughtered and processed through routine market channels so that the carcasses were not retained for measurement.

(g) Grading:

Aherne et al (1974) have reviewed the hog grading system using indices based on total backfat measurement and dressed carcass weight. Total backfat measurement is determined by taking the sum of the maximum depth of shoulder fat plus the maximum depth of loin fat. They indicate that carcasses weighing between 150 and 159 pounds and having an average total backfat measurement of 3.2 - 3.3 inches are given an index of 100. The index changes for every two-tenths of an inch of backfat and through nine carcass weight brackets. These other combinations of backfat and carcass weight are given indices ranging from 87 to 112. Thus pigs having low backfat measurements and carcass weights between 150 and 180 pounds receive the highest index rating. The market price is based on carcasses with a 100 index, so that a carcass receiving an index of 110 would receive 10 percent more per pound than the market price. Similarly, they observed that a carcass with an index of 90 would receive 10 percent less per pound than a 100 index carcass

(h) Record of performance for swine (ROP) carcass measurements

In 1971 a Record of Performance Testing of Swine in Alberta (Harbison and Eagles, 1971) was approved. The carcass score provides an indirect estimate of the combined percent yield of the four lean cuts of a carcass. The estimate is based on an index derived from the following:

1. Carcass length; measured in inches from the front of the first rib to the anterior;
2. Total backfat (3 measurements - maximum visible shoulder and loin fat + minimum visible mid-back fat);
3. Area of loin;
4. Percent ham of side;
5. Ratio of lean area in face of ham to weight of ham.

Estimated Percentage Yield of Trimmed Cuts is obtained by the formula $Y = 51.68 - (3.234 \times X1) + (1.038 \times X2) + (0.485 \times X3) + (11.766 \times X4)$.

where Y = 51.68 (estimated yield a constant term)
X1 = total fat (3 measurements - shoulder, mimimum back and loin)
X2 = Loin area
X3 = % Ham of carcass
$X4 = \dfrac{\text{Area of lean in ham face}}{\text{Ham weight}}$

METHOD OF STATISTICAL ANALYSIS

Biological data for the 8 dietary protein combinations were subjected to analyses of variance. The sources of variation and traits considered are presented in Table 7.

Diets were considered as fixed sources of variation. Notations used to indicate level of significance are: *(P 0.05), **(P 0.01), ***(P 0.001). Multiple comparison of means had significance (P 0.05) based on Duncan's Multiple Range Test (Steel and Torrie 1960). Means not significantly different bear the same subscript. Standard errors of the means[8] are also indicated. In the case of treatment 6 where two female animals died, data of the surviving females were used. Digestibility studies were computed considering diets as a source of variation. Data for feed consumption were calculated on the basis of pig-days and average daily gains were based on the total gain per pen, per phase divided by total weight gained by pigs during the phase under consideration and gain:feed ratios were based on the total feed intake per pen, per phase.

To obtain missing figures of the R.O.P. carcass data an analysis of the multiple regression was performed.

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[8] Standard Error of the Means = $\sqrt{\frac{\text{Error mean square}}{\text{Number of observations.}}}$

It was however not possible to obtain data for treatment 5 in both replicates. While results will exclude this treatment an attempt will be made in discussing carcass characteristics to extrapolate.

TABLE 7: SOURCES OF VARIATION AND NUMBER OF TRAITS STUDIED

Phases	Traits	Diet	Sex	Replicates
Starter	Performance: 5-10 weeks Initial Wts, Final Wts, ADG, ADF, FC.	8	2	2
Grower	10-15 weeks Initial Wts, Final Wts, ADG, ADF, FC.	8	2	2
	Digestibility Studies: DE and DN	8	2	2
	Blood profile	8	2	2
Finisher	15 weeks to Market Wt. Initial Wts, Final Wts, ADG, ADF, FC.	8	2	2
	Carcass characteristics*	8	2	2
Overall	5 weeks to Market Wt. Initial Wts, Final Wts, ADG, ADF, FC.	8	2	2

*Data for 23 animals from various treatment groups, sexes and replicates were not obtained. Multiple regression analysis was performed to estimate these missing figures.

RESULTS AND DISCUSSION

Results of this trial are discussed in terms of performance for the starting, growing and finishing phases on the basis of treatment as well as the parameters measured; viz.

(a) feed intake (FI)

(b) Average daily gain (ADG)

(c) feed conversion efficiency

(d) certain blood constituents

(e) carcass characteristics.

GROWTH PERFORMANCE

Starter phase

Table 8 shows the performance of pigs fed the various diets in the starting phase.

(1) Initial weight

Although the initial weights of weanling pigs used in this trial were balanced as far as possible, there was nearly a significant difference ($P<0.06$) between treatments. Animals in treatment 1 had an average weight of 6.73 kg while those in treatment 4 which was the least, weighed 6.39 kg. There was a highly significant ($P<0.001$) replicate effect. Pigs in replicate 1 weighed more than pigs in replicate 2 (6.99 vs 6.17).

TABLE 8: PERFORMANCE DURING THE STARTER PHASE

Source of Protein	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM	S.E. of Means
Avg Ini. wt (kg)	6.7	6.5	6.6	6.4	6.6	6.7	[illegible].4	6.6	
Avg final wt (kg)	24.5	22.8	23.1	23.3	21.8	22.5	22.3	22.3	
Wt gain (kg)	17.8	16.3	16.5	16.9	15.2	15.8	15.9	15.6	
Animal days	264	264	264	264	264	264	264	264	
F/G (kg feed/ kg gain)	2.30	2.42	2.31	[illegible].22	2.49	2.66	2.45	2.50	0.18
ADF (kg)	1.22	1.16	1.13	1.11	1.12	1.25	1.15	1.15	0.10
ADG (kg)	0.53	0.48	0.49	0.50	0.45	0.47	0.47	0.46	0.02

SE = Standard error
F/G = Feed conversion
ADF = Average daily feed intake
ADG = Average daily gain

(ii) Final weights

There were no differences in the final weights of animals between treatments but the replicate differences observed in the initial weight were also noted here. Since replicate differences are not central to the discussion they are not discussed in detail.

(iii) Average daily weight gain

Animals in all the eight dietary treatments had essentially the same weight gain. This indicates that starter pigs may be fed up to 14.5% low glucosinolate RSM without adverse effects on weight gain. Results with RSM obtained by other workers have varied, probably depending on the source of RSM used as protein supplement. For example, McDonald (1973) studied the effects of level and source of RSM on feed intake by the rat and pig and observed that ADG and ADF tended to be slightly higher for pigs fed a diet containing Bronowski RSM (low glucosinolate) than those fed a diet containing SBM. On the other hand he noted that performance of pigs fed a similar diet in which B. napus RSM provided the only source of dietary protein was extremely poor. Increasing levels of B. napus, he observed, resulted in stepwise reduction in feed intake up to the level where B. napus provided 75% of the dietary protein.

Omole and Bowland (1974) in studies to evaluate a low glucosinolate RSM as partial or complete replacement for SBM in swine diets from weaning to market weight found that source of protein had no influence on gain, suggesting that a low glucosinolate RSM could replace SBM on an isonitrogenous and isocaloric basis.

These results also indicate that starter pigs may be fed unprocessed ground FB of the minor varieties at levels of up to 21%, ie. FB may totally or partially replace SBM on an isonitrogenous basis without any depression in ADG. There was a highly significant replicate effect ($P<0.001$) on weight gain but this may be a function of the initial weight replicate effect indicated above. Sex also had a highly significant effect on weight gain during this starter phase, but there were no interaction between sex and dietary treatment. Barrows gained faster than gilts in all treatments. Bowland (1974) in comparing low glucosinolate RSM, commercial RSM and SBM as protein supplements for growing pigs obtained essentially the same results in sex performance between low glucosinolate RSM and SBM.

Two pigs died at the end of the starter phase in treatment 6 at approximately the same age and weight. Autopsy of one revealed a large vegetative growth affecting the heart which is often seen in Erysipelas but is sometimes caused by Streptococci. In this case, since Streptococci were isolated from the heart valves, cause of death was attributed to this organism and regarded as an isolated case. Cause of death of the second pig was attributed to Enteric Colibacillosis. Thus death of the two animals, one each from both replicates, was not due to dietary treatment.

(iv) Feed intake

Average daily feed intake between treatments did not show any significant differences ($P<0.05$). Since there was minimum wastage of feeds, and consumption levels were generally satisfactory, these results indicate (i) that either RSM or FB at the levels fed can be included in swine starter diets without apparent reduction in feed intake, and (ii) that the various combinations of RSM and FB used in this trial may be fed to this class of pigs.

This conclusion however seems to be variance with results obtained by Bowland (1973) who found that pigs receiving either the "Accepts" fraction of RSM low in glucosinolates (partially dehulled fraction)or a mixture of SBM and this RSM fraction in their diets, ate less per day and gained more slowly than those fed only SBM. However this conclusion agrees with results obtained by Omole and Bowland (1974).

(v) Feed conversion

Although not significant, treatment 4 (75% RSM, 25% FB) showed a slightly better feed conversion than the control treatment. This slight advantage was not however reflected on the average daily gain discussed above.

There appears to be no published information on the use of FB for starting pigs, consequently it is not possible to compare results of this phase.

Grower and finisher phases

Performance data during the grower and finisher phases of this trial are presented in Talbe 9 and 10. Results obtained for ADF, ADG, FC follow similar trends to those obtained in the starter phase. During the finishing phase pigs in some of the lots (treatments 6 and 8) with the lowest gains previously showed the highest gains. However, as none of these ADG values differed significantly it is doubtful if any real compensatory gain occurred.

During the first week in the finisher phase, it was discovered that the automatic water fountain was non-functional in the second replicate of treatment

TABLE 9: PERFORMANCE DURING THE GROWER PHASE

Source of Protein	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM	S.E. of Means
Av. ini. wt (kg)	24.5	22.8	23.1	23.2	21.7	25.4	22.3	22.2	
Avg final wt (kg)	51.6	48.6	49.4	48.3	48.5	51.7	46.4	46.0	
Avg wt gain (kg)	27.1	25.8	26.2	25.1	26.7	26.2	24.3	23.7	
Animal days	280	280	280	280	280	280	280	280	
F/G	3.14	3.13	3.16	3.07	3.03	3.44	2.89	3.41	0.17
ADF (kg)	2.45	2.45	2.37	2.21	2.33	2.44	2.02	2.32	0.15
ADG (kg)	0.78	0.74	0.75	0.72	0.77	0.71	0.70	0.68	0.03

TABLE 10: PERFORMANCE DURING THE FINISHER PHASE

Source of Protein	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM	S.E. of Means
	—	—	—						
Avg. ini. wt (kg)	51.6	48.6	49.4	48.3	48.5	51.7	46.6	46.0	
Avg. final wt (kg)	87.7	88.5	88.1	89.1	87.2	87.8	87.8	87.9	
Avg. wt. gain (kg)	36.1	36.7	38.7	40.7	38.7	36.1	41.2	41.9	
Animal days	392	434	427	413	406	350	462	434	
F/G	4.42	4.68	4.37	4.09	4.39	4.33	4.21	4.35	0.15
ADF (kg)	3.27	3.46	3.19	3.23	3.34	3.51	3.03	3.39	0.17
ADG (kg)	0.74	0.74	0.73	0.79	0.76	0.81	0.72	0.78	0.02

1. Deprived of water supply, pigs in this treatment actually lost weight when weights were recorded the next week, but it is difficult to know whether this water restriction had any adverse effects for the entire finishing period.

(c) Overall data

These data represent results obtained from the start of the experiment to the finish.

Average daily gain and feed conversion

Results show no significant differences ($P<0.05$) between treatments and suggest that source of dietary protein had no significant effects on feed intake or rate of growth from weaning to market weight.

Previous trials using commercial RSM (Bowland and Bell 1972) had indicated that RSM fed at levels as high as those used in the present study tended to reduce feed intake and this was attributed to the presence of glucosinolates (McDonald 1972) or lack of palatability of RSM (Bowland 1972). Omole and Bowland (1974) fed isonitrogenous and isocaloric diets with protein supplements of either SBM, low glucosinolate RSM or a combination of SBM and RSM to pigs from weaning to market weight. They noted that source of protein had no influence on gain suggesting that

TABLE 11: PERFORMANCE DURING THE OVERALL EXPERIMENT

Source of Protein	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM	S.E. of Means
Avg. ini. wt (kg)	6.7	6.5	6.6	6.4	6.6	6.7	6.4	6.6	
Avg. final wt (kg)	87.7	88.5	88.1	89.1	87.2	87.8	87.8	87.9	
Avg. wt. gain (kg)	81.0	81.9	81.4	82.7	80.7	81.1	81.4	81.2	
Total feed (kg)	286.9	311.7	298.6	281.2	287.4	310.2	284.7	304.2	
Animal days	964	1006	999	985	978	922	1034	1006	
Avg. no. of days on test	120.5	125.8	124.9	123.1	122.3	115.3	129.3	125.8	
F/G	3.55	3.82	3.62	3.40	3.56	4.09	3.49	3.72	0.11
ADF (kg)	2.38	2.48	2.39	2.28	2.35	2.62	2.20	2.42	0.10
ADG (kg)	0.67	0.65	0.65	0.67	0.66	0.64	0.63	0.65	0.02

a low glucosinolate RSM could replace SBM on an isonitrogenous and isocaloric basis. Essentially the same results and trends are obtained in this trial.

Stothers (1974) has reviewed FB trials at the University of Manitoba on pigs initially weighing approximately 36 kg. He indicated that in general where FB have replaced half the supplemental SBM, performance has been intermediate to that recorded for the barley - SBM ration and the barley-FB ration; that is, barley-SBM>barley FB/SBM>barley/FB. Stothers (1974) also noted that FB results with pigs initially weighing 22 kg have been inconsistent. His results had indicated on an average that pigs fed FB consumed 20% less feed, had 20% lower gains and a 10% impairment of feed efficiency. He noted however that variation between tests had been very large; ranging from 5% to over 30% impairment in feed consumption, gain and feed efficiency.

Castaing and Levittel (1974) on the other hand, in their studieson progressive stustitution of SBM by FB in growing-finishing pig diets incorporated FB at levels of 0 - 36% of the diet. They noted that during the trial no significant differences were observed between diets with respect to feed intake, growth rate and feed conversion. Thus they concluded that FB can be used at a high level in pig diets without modifying performances. Results of this trial has confirmed Castaing's work. It must be noted however that in swine diet supplementation with FB, results have so far been very conflicting. There is the need for continued research in this direction.

CARCASS CHARACTERISTICS

Data on grade, liveweight, carcass weight, dressing percentage, percentage ham lean over ham face, loin eye area, length of side, total shoulder fat and percentage weight of ham over carcass weight are presented in Table 12.

No significant differences between treatments, were observed in any of the carcass measurements made. However, the typical significant differences ($P<0.05$) between barrows and gilts reported by Bowland and Berg (1959) in their work on the influence of strain and sex on the relationship of protein to energy in the rations of growing and finishing bacon pigs, were also observed in this trial. Significant differences ($P<0.05$) between sexes were observed in loin eye area, total shoulder fat, percentage lean ham over fat and percentage weight of ham over carcass with gilts being superior to barrows in all cases.

TABLE 12: MEAN VALUES FOR CARCASS CHARACTERISTICS

Treatment		1	2	3	4	5	6	7	8
Dietary protein Supplements		SBM	RSM	FB	75/25 RSM-FB	50/50 RSM-FB	25/75 RSM-FB	50/50 SBM-FB	50/50 SBM-RSM
Grade index	Male	102.7	100.5	101.5	104.0	-	94.5	98.5	101.0
	Female	101.5	98.7	105.5	101.3	-	104.5	103.7	100.0
	Avg.	102.1	99.6	103.5	102.6	-	99.5	101.1	100.5
Liveweight (kg)	Male	89.0	91.5	87.5	93.5	-	86.5	86.5	89.5
	Female	85.0	83.0	86.5	89.0	-	86.7	89.6	83.7
	Avg.	87.0	87.2	87.0	91.2	-	86.6	87.8	86.6
Carcass wt.(kg)	Male	69.9	72.3	69.8	74.3	-	72.0	68.4	72.4
	Female	66.6	65.6	68.2	70.0	-	66.6	72.2	65.9
	Avg.	68.7	68.9	69.0	72.1	-	69.3	70.3	69.1
Dressing percentage	Male	78.5	79.0	79.7	76.7	-	80.9	79.5	80.9
	Female	78.3	79.0	78.8	78.6	-	76.8	80.5	78.6
	Avg.	78.4	79.0	79.2	77.6	-	78.8	80.0	79.7
Ham lean / Ham fat (%)	Male	51.8	51.9	32.5	49.2	-	38.0	49.7	36.4
	Female	51.2	55.2	46.5	57.3	-	51.4	60.5	39.8 *
	Avg.	51.5	53.5	39.5	53.2	-	44.7	55.1	38.1
Loin eye area (sq. cm.)	Male	29.8	27.7	31.3	28.2	-	22.7	28.2	29.5
	Female	29.0	31.5	30.5	30.3	-	31.9	33.4	31.9 *
	Avg.	29.4	29.6	30.9	29.2	-	27.3	30.8	30.7
Length of side (cm.)	Male	76.4	76.4	76.7	76.1	-	73.1	75.1	74.6
	Female	62.2	75.9	77.3	77.0	-	76.6	75.1	74.7
	Avg.	69.3	76.1	77.0	76.5	-	74.8	75.1	74.6
Avg. back[1] fat (cm.)	Male	9.6	10.4	9.6	11.5	-	13.2	11.2	10.4
	Female	9.6	9.4	8.6	10.2	-	8.6	9.4	9.6 *
	Avg.	9.6	9.9	9.1	10.9	-	10.9	10.1	9.9
Wt. of ham / Carcass wt. (%)	Male	27.1	26.5	26.8	24.9	-	25.0	15.7	26.7
	Female	26.8	26.5	26.8	26.5	-	27.6	27.2	28.0 *
	Avg.	26.9	26.5	26.8	25.7	-	26.3	26.4	27.3

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[1] Avg. of three fat measurements at the shoulder, minimum back and loin.

BLOOD CONSTITUENTS

Table 13 shows the mean values for the blood constituents measured.

(a) Protein bound iodine and thyroxine

These parameters were not significant between treatments in this experiment. The importance of this lies in the fact that in the past high levels of RSM in the diet had tended to impart hypothyroidism in pigs as obtained from total weight, histological sections and I^{131} turnover rate of the thyroid gland and this was attributed to the presence of myrosinase and glucosinolates (Hussar and Bowland 1959). Results of this trial indicate that RSM low in glucosinolates and low in erucic acid fed at levels of up to 15% produced no adverse effects on growth performance. There was a highly significant replicate effect (P 0.001). Since blood samples were taken at about the same age, the reason for replicate variation is hard to explain.

Protein bound iodine and thyroxine levels in blood plasma are indicative of the thyroid activity of an animal. The values of these, their relation to thyroid activity, the function of the thyroid hormone and its chemistry in relation to

TABLE III: MEAN VALUES FOR BLOOD CONSTITUENTS

Treatment**	P.B.I.*	T4* Thyroxine	Ca§	P§	Gluc§	B.U.N.§	Uric§ Acid	CHOL§	T. † Prot.	ALB†	BILI§	ALK-P●	LDH●	SGOT●
1. SLM	4.7	4.7	11.2	10.1	151	15	0.5	118	6.6	3.7	0.1	183	547	103
2. PSM	5.9	5.0	11.0	9.6	142	15	0.3	136	6.5	3.5	0.1	214	512	92
3. FB	5.0	5.5	11.0	9.4	119	16	0.3	123	6.7	3.6	0.1	171	515	101
4. 75/25 RSM-FB	4.4	5.2	11.0	9.5	113	14	0.4	119	6.5	3.5	0.1	178	511	93
5. 50/50 RSM-FB	4.2	4.9	11.3	9.5	124	15	0.2	120	6.5	3.7	0.2	181	499	79
6. 25/75 RSM-FB	4.4	4.5	11.2	10.3	127	15	0.2	130	6.7	3.6	0.9	173	510	92
7. 50/50 SRM-FB	6.1	5.2	10.8	9.3	115	14	0.2	115	6.4	3.6	0.7	167	494	84
8. 50/50 SRM-PSM	4.7	5.3	11.5	10.2	115	14	0.1	122	6.6	3.7	0.6	194	531	87
SE of Means	0.85	0.37	0.29	0.16	11.2	1.1	0.11	4.2	0.19	0.17	0.06	15.3	36.9	11.3

** Units are average of means

* mcg/100 ml

§ mg/100 ml

† g/100 ml

● mU/ml litre

the protein sources and intake, have been discussed in the Literature Review.

(b) Calcium and phosphorus

Table 13 shows the mean average values of serum calcium, alkaline phosphatase, and phosphorus. Analysis of calcium and alkaline phosphatase showed no significant differences between treatment but there was significant differences (P< 0.01) in phosphorus levels. Treatments 6 and 8 differed in blood phosphorus levels from other treatments. The reason for this is difficult to explain in terms of protein sources or disease situation which, if present, must be subclinical.

(c) Alkaline phosphatase

There was no significant difference in alkaline phosphatase levels between treatments. This may support results obtained in calcium and phosphorus tests and may indicate that there were no adverse effects in the metabolism of these elements due to source of protein. It may also indicate that source of dietary rpotein did not produce subclinical symptoms of obstructive jaundice.

(d) Albumin, BUN, and TP

Table 13 also shows the average values of serum protein albumin, BUN and TP. Analysis shows no treatment significant differences in albumin fraction, BUN or TP.

There was however significant differences ($P < 0.01$) between replicates and sexes in BUN and TP. Barrows had more BUN and TP than gilts. Since plasma protein levels indicate rat rates of protein metabolism, results may indicate that gilts possess inherent factors which make them unable to metabolize proteins at the same rate as barrows. It may also indicate that the protein source contained factors which impair protein metabolism in the liver of female pigs.

Uric Acid

Results show that there were no significant differences ($P < 0.05$) in uric acid levels between treatments. This constituent is however of little relevance to the present study and is therefore not discussed in detail.

Bilirubin

Results show no differences between treatments This may confirm results obtained by BUN and TP tests and also indicate that protein source had no adverse effects on liver functions.

LDH and SGOT

Significant differences were not obtained in the levels of these enzymes. This may indicate that liver problems are not encountered when either RSM low in glucosinolates and erucic acid or ground unprocessed

FB replace SBM on an isonitrogenous basis in swine feeding.

(h) Glucose

Results showed no significant differences between treatments in blood glucose levels. This may indicate that carbohydrate metabolism was similar in the various treatments. Since the liver is involved in glucose metabolism and supply, results may also indicate and/or confirm bilirubin tests; that source of dietary protein did not cause any liver problems.

The values were compared with data obtained by Miller et al (1961) and Perrin (1975, personal communition) and were found to be similar; suggesting that the values are within the normal range expected of pigs in this age group.

DIGESTIBILITY STUDIES

Estimation of digestibility was by the 4N-HCl method. McCarthy et al (1974) indicate that there is close agreement between this method and the total fecal collection method.

Results of the digestibility studies are shown in Table 14. Data are presented on gross energy of the diet, digestibile energy (DE), gross nitrogen intake and digestible nitrogen (DN) intake of pigs in the various treatments.

No significant differences in digestibility coefficients of the diets or in daily intake were noted either for DE or DN between replicates or between treatments. Coefficients for DN were between 76.5 and 79.8 percent. These figures are lower than those obtained by other workers. Stothers (1974) indicates that protein digestibility data obtained from trials in the University of Manitoba for unprocessed ground FB compared quite favorably with SBM protein. Hebblethwaite and Davis (1971) cite Waring and Shannon (1969) as indicating that true digestibility coefficients (using colostomised laying hens) of the crude protein of spring beans was found to be 84 percent and winter beans 81 percent. Bowland

TABLE 14: DIGESTIBILITY STUDIES WITH 38 kg PIGS

Treatment	1 SBM	2 RSM	3 FB	4 75/25 RSM-FB	5 50/50 RSM-FB	6 25/75 RSM-FB	7 50/50 SBM-FB	8 50/50 SBM-RSM
No. of pigs	8	8	8	8	8	6	8	8
ADF (kg)	2.45	2.37	2.21	2.21	2.33	2.44	2.02	2.32
Energy								
Digestibility %	74.1	74.0	77.0	76.1	78.2	73.2	74.5	75.7
Gross energy/kg (kcal)	3771	3867	3728	3858	3694	3859	3716	3730
DE/kg (kcal)	2794	2862	2870	2936	2888	2827	2769	2725
Total DE intake per day (kcal)	6846	7012	6802	6490	6728	6898	5593	6554
Protein (P) and Nitrogen (N)								
N. Digestibility (%)	77.7	76.5	79.3	77.0	79.8	77.6	78.2	79.7
Gross P. intake (g/kg)	162	160	161	168	163	162	163	160
D.P. intake (g/kg)	1[illegible]6	122	128	129	130	126	127	127
Avg. daily D.P. intake (g)	308	300	303	286	303	307	257	296

and Orok (1972-73) in their trial on RSM and PNM as complimentary protein supplements for starting - growing pigs obtained DN coefficients of between 85.8 and 93 percent which as indicated previously are higher than values obtained in the present trial.

There was no significant depression in the DE of diets with 100% replacement of SBM by RSM or FB. There was also no evidence of lowered DE when various combinations of RSM, FB or SBM were fed as protein supplements. The coefficients of 76 ± 2% of the various treatments are lower than values obtained by Bowland (1972) who in his work on unprocessed RSM treated with propionic acid in diets of growing pigs obtained an average DE of 85.3 percent. The reason for the lower values obtained in the present trial cannot be determined.

SUMMARY

Studies on the supplemental value of new double low (low glucosinolate, low erucic acid) RSM and of FB for growing and finishing pigs were carried out at the Animal Science Department, The University of Alberta, Edmonton Research Station from April to September 1974. The primary purpose of the study was to assess the effect of the supplemental protein sources and their various combinations on feed intake, feed conversion efficiency, daily gain and carcass characteristics of weanling pigs to market weight.

The experiment showed that weanling pigs consumed much the same amount of feed in the various treatment groups. There were no indications in the trial that pigs at this stage of growth gained at a slower rate than was expected (A.R.C. 1967). No significant differences in feed consumption were observed between treatments during this period. There were also no significant differences in feed conversion efficiencies. Animals in all treatment groups took a similar number of days to get to approximately 20 kg liveweight each.

Results of this experiment indicate that low glucosinolate varieties of RSM such as used in this trial

could replace SBM on an isonitrogenous basis in pig weaner diets. Results also show that unprocessed ground FB can be fed to weanling pigs at levels of up to 26% of the diet without adverse effects on feed intake and growth rate. Combinations of RSM and FB or SBM and either RSM or FB can also be fed to weanling pigs without reduction in performance. In growing and finishing periods the same trends outlined above were seen.

Carcass characteristics of animals in the various treatment groups were not affected by supplemental protein source indicating that RSM low in glucosinolates and unprocessed FB were of similar value to SBM as protein supplements. Levels of blood constituents of pigs in the eight treatments were similar showing no abnormal changes in certain fractions which may indicate subclinical malfunction of any organ involved in metabolism.

Digestibility of energy and nitrogen, though slightly lower than expected, were similar for all treatments indicating no differences in utilization of RSM or FB compared with SBM. The present experiment demonstrated that RSM low in glucosinolates and low in erucic acid or unprocessed ground FB of good quality should result in performance and digestibility similar to SBM when they are used as the major protein source in barley-based diets.

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APPENDIX

METHODOLOGIES OF INDIVIDUAL BLOOD TESTS[1]

The following describes the flow system and chemistries of the individual methods used in determining some of the blood characteristics. After each sample is aspirated, it is split five ways:

Stream 1 (SGOT) - The method is based on the procedure of Morgenstern, et al., Clin. Chem. 12: 95-11 (1966). The oxolacetic acid produced by the action of the enzyme is dilyzed and then reacted with the diazonium salt of N-butyl-4-methoxy-metanilomide (Azoene Fast Red, PDC). Serum samples are incubated with aspartate-ketoglutarate substrate at 45° C. dialyzed against water and then mixed with the dye disolved in citrate buffer containing 20% ethanol. Color is developed at 45° C and the product is read at 460 mu. in a 15 mm flowcell.

Stream 2 (Alkaline Phosphatase) - This is the method of Morgenstern et al., Clin. Chem., 11, 876 (1965) which is a modification of the procedure of Bessey et al., J. Biol. Chem., 164: 321 (1946). The procedure is based on the enzymatic hydrolysis of p-nitrophenyl phosphate during incubation at 37° C. Following incubation, the free p-nitrophenol is dialyzed into a 2-amino-2-methyl-1-propanol recipient buffer. The dialyzed p-nitrophenol is highly colored under alkaline conditions and thereby provides its own chromagen. Dialysis eliminates the interference of bilirubin and the need for blank correction. The absorbance of p-nitrophenol is measured at 410 mu.

Stream 3 (Uric Acid) - This procedure for the measurement of uric acid is based on the reduction of phosphotungstate complex to a phosphotungstite complex. Sodium tungstate is used as a stable alkalizing agent and hydroxylamine intensifies the color. It is based on the work of A.W. Musser and C. Ortigoza (Tech. Bull. of the Reg. of Med. Techs. 36: 21-25 (1966), who automated the original method of M. Simoes Sobrinho, J., Lab. and Clin. Med., 65: 665-668 (1965). In addition, greater specificity has been achieved by alkaline pretreatment of the diluent stream as described by H. Nishi, Clin. Chem. 13: 12-18 (1967). Serum is diluted and treated with NaOH solution. Phosphotungstic acid is added and the color produced is measured at 660 mu in a 15 mm flowcell.

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Stream 4 (Inorganic Phosphate) - This is a modification of the standard N method, based on the formation of phosphomolybdic acid, which is then reduced by stannous chloride-hydrazine. The use of this more stable reducing agent was first reported by R.O. Hurst (Can. Jour. of Biochem. 42: 287 (1964) and adapted to the Auto Analyzed by M. Krml (Clin. Chim. Acta. 13: 442 (1966). Serum is mixed with, and also dialyzed against 1% H_2SO_4. The dialyzable phosphate is then mixed with an acidic solution of ammonium molybdate with the formation of phosphomolybdic acid and this is immediately reduced by stannous chloride-hydrazine. The absorption of the blue product is measured at 660 mu in a 15 mm flowcell.

Stream 5 (T.P., Albumin, Calcium, Glucose, BUN, LDH, Cholesterol and Bilirubin) - is diluted with water, and then this "main sample stream" is further split into 11 sub-streams:

a. Glucose - The method is a modification of the procedures of M.E. Brown, Diabetes 10: 60-62 (1961); and D. Bittner and M. McCleary, Am. J. Clin. Path. 40: 423-424. Abst. (1963). A cupric-neoproine chelate is reduced by glucose in an alkaline medium resulting in a highly colored cuprous-neocuproine complex. After heating at 90° C., the absorbance is measured in a 15 mm flowcell at 460 mu. Interference by ascobic acid and sulpydryl groups is reduced by treating the dialysate with sodium carbonate before addition of the colour reagent.

b. Blood Urea Nitrogen - A modification of the method of Marsh et al., Clin. Chem. 11: 624-627 (1965). A colored product is formed when urea, in relative weak acid solution reacts with diacetyl monoxime. The presence of thiosemicarbazide and ferric ion intensifies the colour of the reaction. The mixture is heated at 90° C for colour development, and read in a 15 mm flowcell at 520 mu.

c. Lactic Dehydrogenase- The method is based on the procedure of Hochella and Weinhouse, Anal. Biochem. 13: 322-335 (1965). Lactic dehydrogenase catalyzes the oxidation of L-Lactate by NAD in the lactate to pyruvate reaction. Enzyme activity is determined by coupling this reaction to the reduction of the tetrazolium dye (INT) with diaphorase serving as an intermediate electron carrier. All reactions are carried out at 37° C and the absorbance is measured at 505 mu in a 15 mm flowcell. The serum blank is determined by substituting blank solution fro the DPN-diaphorase reagent. The diluted serum sample is carried through the same steps in the blank channel as in the analytical channel, and the absorption is measured at 505 mu in a 15 mm flowcell. The blank is automatically subtracted by differential colourimetry.

d. LDH Blank - Same as assay except that a blank solution is used in place of DPN-diaphorase.

e. Calcium - This procedure is a modification of the method of G. Kessler and M. Wolfman, Clin. Chem. 10: 686-703 (1964). The new method, as reported by H.J. Gitelman (Anal. Biochem. 18: 521, (1967), incoporates the use of 8-hydroxyquinoline to virtually eliminate the interference of magnesium. The diluted serum sample is mixed with 0.30 N hydrochloric acid containing 8-hydroxyquinoline to release protein-bound calcium and combine with the magnesium. This is dialyzed into a recipient stream of Cresolphthalein Complexone, Again containing 8-hydroxyquinoline. A coloured complex between calcium and dye is formed upon addition of diethylamine. The developed colour is measured in a 15 mm flowcell at 570 mu.

f. Cholesterol - This method is based on a modification (Huang et al., Anal. Chem., 33 1405 (1961) of the Liberman-Burchard reagent for use in the direct determination of serum cholesterol. Dilute serum is mixed with a stable reagent composed of acetic acid, acetic anhydride and sulfuric acid. The developed colour is read at 630 mu in a 15 mm flowcell.

g. Total Bilirubin - The N Method for total bilirubin is based on the procedure of Jandrassik and Grof, Biochem. Z. 297: 81 (1964). Bilirubin is reacted with diazotized sulfanilic acid in the presence of a caffeine-sodium benzoate reagent to form coloured azobilirubin.

The alkaline azobilirubin is measured at 600 mu in a 15 mm flowcell. The blank is determined by using sulfanilic acid in place of the diazo reagent. The absorption is measured at 600 mu. The blank is automatically subtracted by differential colourimetry.

h. Total Protein - A standard Auto-analyzer N Method using a modified biuret reaction. Copper, in alkaline solution, forms a purple complex with the peptide linkages of amino acids in a protein. The protein stream is mixed with the biuret reagent and the developed colour is measured at 550 mu in a 15 mm flowcell. The serum blank is determined by diluting the sample with alkaline iodide solution and measuring the absorption at 550 mu in a 15 mm flowcell. The blank is automatically subtracted by differential colourimetry.

APPENDIX TABLE I

F - VALUES AND PROBABILITIES FOR STARTER PHASE

Source of variation	d.f.	Initial wt. M.S.	Initial wt. Prob.	Final wt. M.S.	Final wt. Prob.	Gain M.S.	Gain Prob.
Treat.	7	0.1176	0.054	5.663	0.243	5.370	0.228
Expt.	1	4.1769	0.000***	64.401	0.003**	101.380	0.001***
Error (TE)	7	0.0322		3.274		2.984	
Sex	1	0.4144	0.543	24.751	0.068	31.570	0.008**
ST	7	0.3299	0.924	5.574	0.494	4.227	0.241
Error (SE+STE)	8	1.0265		5.583		2.516	

Source of variation	d.f.	A.D.F. M.S.	A.D.F. Prob.	A.D.G. M.S.	A.D.G. Prob.	FC M.S.	FC Prob.
Treat.	7	0.1224	0.754	0.1228	0.277	0.5736	0.583
Expt.	1	0.1024	0.063	0.8556	0.013*	0.3802	0.474
Error	7	0.2104		0.7705		0.6639	

APPENDIX TABLE II

F - VALUES AND PROBABILITIES FOR GROWER PHASE

Source of variation	d.f.	Initial wt. M.S.	Initial wt. Prob.	Final wt. M.S.	Final wt. Prob.	Gain M.S.	Gain Prob.
Treat.	7	12.215	0.224	33.786	0.341	11.209	0.336
Expt.	1	84.871	0.009**	25.000	0.346	17.745	0.181
Error (TE)	7	6.711		24.509		8.043	
Sex	1	4.151	0.504	47.266	0.122	23.401	0.021*
ST	7	10.825	0.367	44.007	0.087	11.757	0.032*
Error (SE+STE)	8	8.478		15.789		2.825	

Source of variation	d.f.	A.D.F. M.S.	A.D.F. Prob.	A.D.G. M.S.	A.D.G. Prob.	FC M.S.	FC Prob.
Treat.	7	0.4363	0.5091	0.2371	0.338	0.6932	0.426
Expt.	1	0.8409	0.211	0.3906	0.174	0.4193	0.033*
Error	7	0.4446		0.1706		0.5986	

APPENDIX TABLE III

F - VALUES AND PROBABILITIES FOR FINISHER PHASE

		Initial wt.		Final wt.		Gain	
Source of variation	d.f.	M.S.	Prob.	M.S.	Prob.	M.S.	Prob.
Treat.	7	33.786	0.341	2.391	0.975	38.096	0.063
Expt.	1	25.000	0.346	83.266	0.034*	199.520	0.004**
Error (TE)	7	24.509		11.998		11.114	
Sex	1	47.226	0.122	280.560	0.015*	97.516	0.013
ST	7	44.007	0.087	36.938	0.375	23.435	0.117
Error (SE+STE)	8	15.789		29.391		9.570	

		A.D.F.		A.D.G.		FC	
Source of variation	d.f.	M.S.	Prob.	M.S.	Prob.	M.S.	Prob.
Treat.	7	0.4898	0.592	0.2225	0.085	0.5888	0.3482
Expt.	1	0.2401	0.083	0.4000	0.487	0.5891	0.008**
Error	7	0.5874		0.7428		0.4336	

APPENDIX TABLE IV A

F - VALUES AND PROBABILITIES FOR OVERALL PHASE

Source of variation	d.f.	Overall initial wt. M.S.	Overall initial wt. Prob.	Overall final wt. M.S.	Overall final wt. Prob.	Overall gain M.S.	Overall gain Prob.
Treat.	7	28.25	0.296	19.37	0.682	4.66	0.247
Expt.	1	49.36	0.147	5.07	0.684	22.79	0.023
Error (TE)	7	18.55		28.11		2.72	
Treat.	7	28.25	0.008**	19.37	0.027*	4.66	0.833
PT	14	8.93	0.226	11.24	0.116	25.00	0.044*
PE	2	32.34	0.022*	83.80	0.0004***	147.92	0.000*
Error (PTE)	14	6.35		5.83		9.71	
P	2	29024	0.000***	68950	0.000***	8507.0	0.000*
PT	14	8.93	0.550	11.24	0.728	25.01	0.553
Error (PE+PTE)	16	9.60		15.58		26.99	
Expt.	1	49.36	0.378	5.07	0.824	22.79	0.200
Treat.	7	28.25	0.858	19.37	0.985	4.66	0.934
ET	7	18.54	0.949	28.11	0.958	2.72	0.982
S	1	22.79	0.548	272.65	0.111	137.79	0.003**
ES	1	0.24	0.950	0.12	0.973	0.022	0.968
ST	7	35.14	0.776	59.58	0.760	12.20	0.507
SET	7	20.84	0.931	43.81	0.874	7.38	0.787
Error (R/SET)	32	61.84		101.25		13.32	
P	2	29024	0.000***	68950	0.000***	8507.0	0.000***
PE	2	32.34	0.021*	83.80	0.001**	147.92	0.000***
PT	14	8.93	0.358	11.24	0.487	25.01	0.173
PET	14	6.35	0.667	5.83	0.921	9.71	0.894
PS	2	14.52	0.170	39.96	0.037*	7.35	0.661
PES	2	0.71	0.915	0.49	0.958	0.22	0.988
PST	14	10.01	0.260	13.47	0.319	13.61	0.697
PSET	14	3.91	0.930	7.23	0.847	4.79	0.995
Error (PR/SET)	64	7.97		11.51		17.68	

R = animals
S = sex
T = treatment
E = replicates
P = phase

APPENDIX TABLE IV B

F - VALUES AND PROBABILITIES FOR OVERALL EXPERIMENT

		A.D.F.		A.D.G.		FC	
Source of variation	d.f.	M.S.	Prob.	M.S.	Prob.	M.S.	Prob.
Treat.	7	0.0149	0.614	0.0004	0.652	0.0351	0.029
Expt.	1	0.0812	0.076	0.0002	0.608	0.2525	0.013*
Error	7	0.0178		0.0005		0.0228	

APPENDIX TABLE V

TABLE OF MEAN SQUARE VALUES - CARCASS CHARACTERISTICS

	Experiment	Treatment	Sex	Interaction	Residual
d.f.	1	1	1	13	15
Grade	3.60	11.86	32.24	26.90	18.60
Live wt.	105.62*	10.11	27.57	19.07	45.45
Carcass wt.	44.60	7.07	49.63	16.82	40.78
Dressing % age	1.21	2.26	6.61	2.38	2.62
Av. Ham face	124.60*	6.67	18.28	11.39	16.53
Av. Ham lean	3.98	8.73	27.67	6.39	9.68
% Ham lean/fat	133.00	98.97	420.7 *	52.05*	14.59
L.E.A.	0.90*	0.184	2.52*	0.167	0.620
Length of side	1.08	2.622	2.99	3.67	4.67
Total shoulder fat	0.008	0.343	3.02*	0.317	0.154
Wt. of ham	0.74	0.081	0.032	0.315	0.416
Wt. of side	16.64	1.267	6.434	3.279	8.879
% Wt. of ham/carcass	0.129	1.323	7.86*	1.491	1.277

APPENDIX TABLE VI

STATISTICAL COMPUTION FOR CARCASS CHARACTERISTICS

Source	d.f.	S.S.
Experiment	1	R[E,T,S] - R[T,S]
Treatment	6	R[E,T,S] - R[E,S]
Sex	1	R[E,T,S] - R[E,T]
Interaction	13	R[E,T,S,ET,ES,TS] - R[E,T,S]
Residual	15	Total S,S - R[E,T,S,ET,ES,TS]

The statistical analysis of the carcass data were computed as shown in Appendix Tables II and III.

APPENDIX TABLE VII

ANOVA 5 PROTEIN DIGESTIBILITY

"Y = M + A + B + E"
where A = Treatment
B = Experiment

Source of variation	d.f.	S.S.	M.S.	F	Significance
Treatment	7	21.63014	3.09002	3.56	N.S.
Experiment	1	1.15026	1.15026	1.32	N.S.
Error	7	6.07917	0.86846		
Total	15	28.85959			

APPENDIX TABLE VIII

ANOVA 5 ENERGY DIGESTABILITY

"Y = M + A + B + E"
where A = Treatment
B = Experiment

Source of variation	d.f.	S.S.	M.S.	F	Significance
Treatment	7	39.6783	5.6683	2.28	N.S.
Experiment	1	9.22641	9.22641	3.71	N.S.
Error	7	17.39194	2.48456		
Total	15	66.2966			